# Variations in Stratospheric $Cl_y$ Between 1991 and the present

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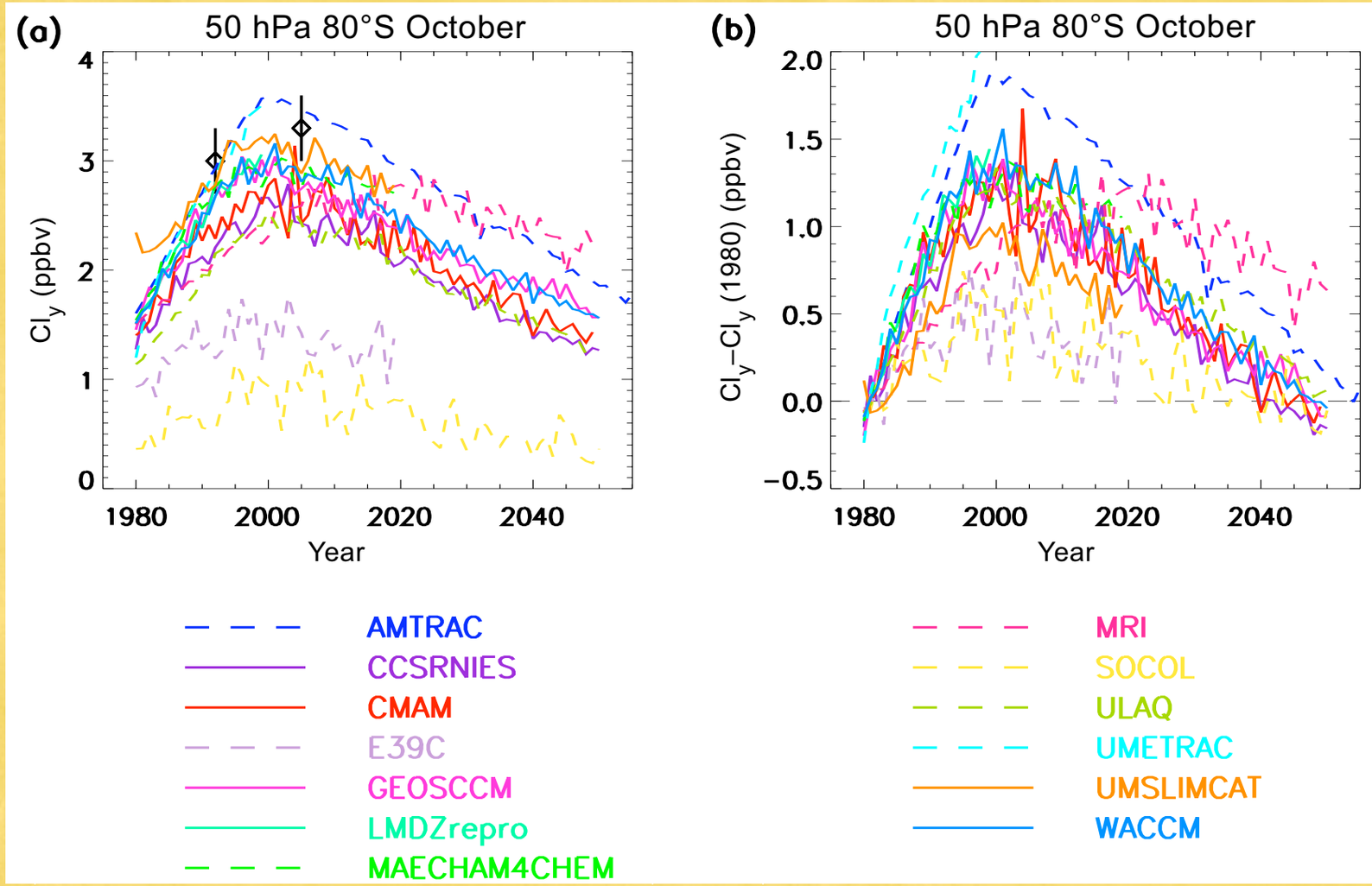
- We need to know the distribution of inorganic chlorine ($Cl_y$) in the stratosphere to:
  - Attribute changes in stratospheric ozone to changes in halogens.
  - Assess the realism of chemistry-climate models.



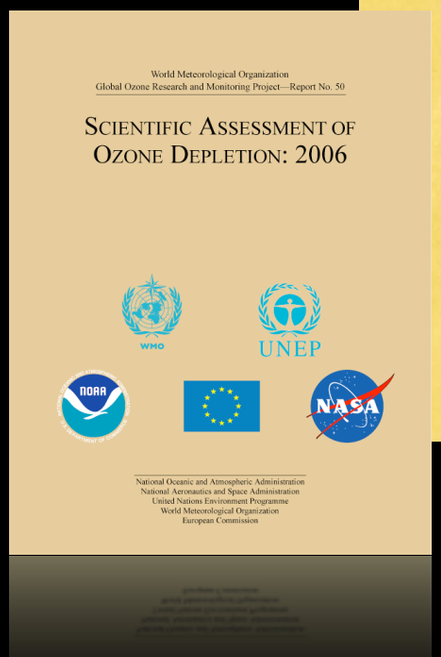




**Figure 6-8.** October zonal mean values of total inorganic chlorine (Cl$_y$ in ppb) at 50 hPa and 80°S from CCMs. Panel (a) shows Cl$_y$ and panel (b) difference in Cl$_y$ from that in 1980. The symbols in (a) show estimates of Cl$_y$ in the Antarctic lower stratosphere in spring from measurements from the UARS satellite in 1992 and the Aura satellite in 2005, yielding values around 3 ppb (Douglass et al., 1995; Santee et al., 1996) and around 3.3 ppb (see Figure 4-8), respectively.

Constrained by a limited number of $Cl_y$ observations

A large range of $Cl_y$ in the model simulations

**21st CENTURY OZONE LAYER**

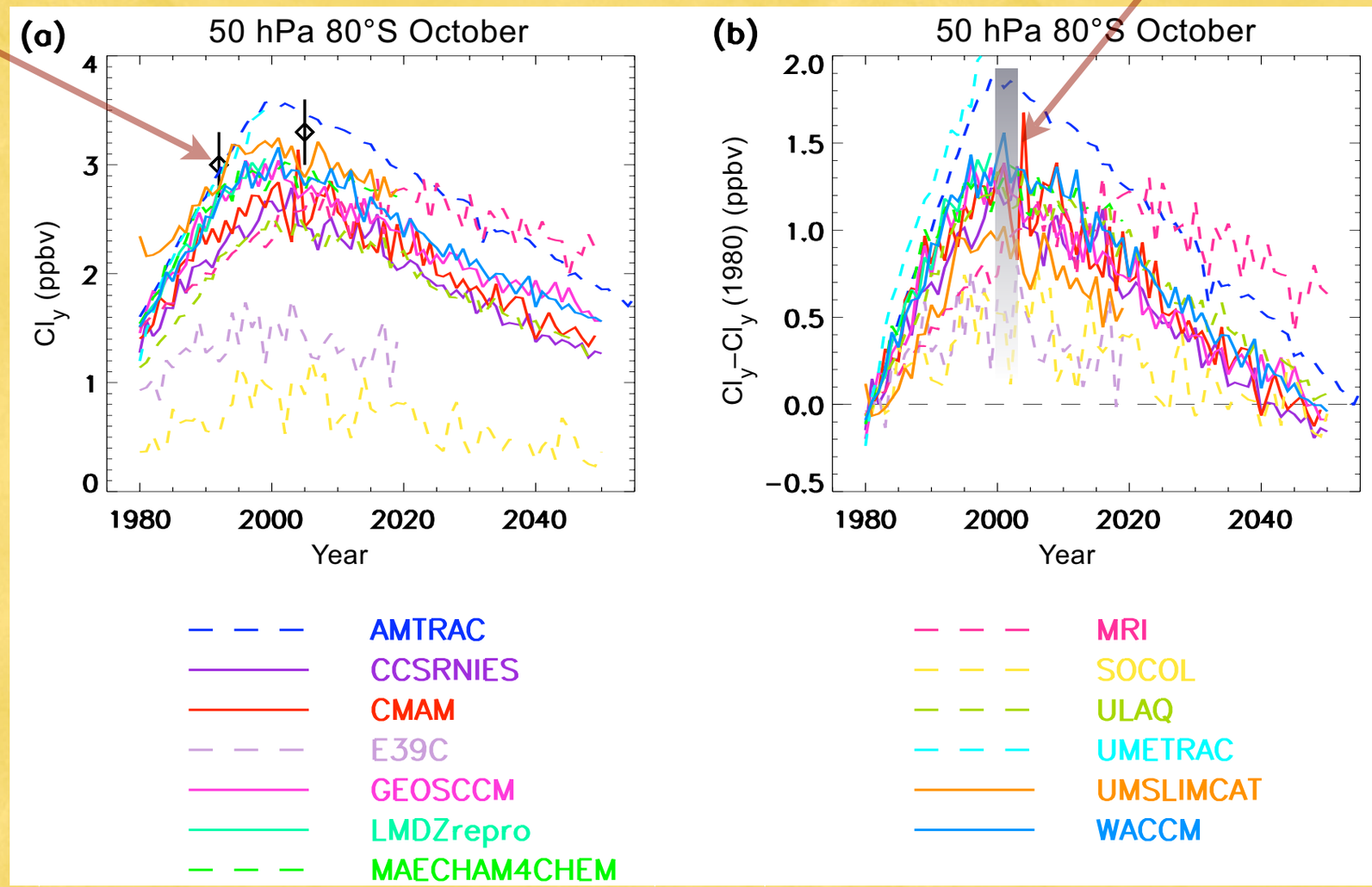



**Figure 6-8.** October zonal mean values of total inorganic chlorine ($Cl_y$ in ppb) at 50 hPa and 80°S from CCMs. Panel (a) shows $Cl_y$ and panel (b) difference in $Cl_y$ from that in 1980. The symbols in (a) show estimates of $Cl_y$ in the Antarctic lower stratosphere in spring from measurements from the UARS satellite in 1992 and the Aura satellite in 2005, yielding values around 3 ppb (Douglass et al., 1995; Santee et al., 1996) and around 3.3 ppb (see Figure 4-8), respectively.

$$Cl_y = HCl + ClONO_2 + ClO + HOCl + 2Cl_2O_2 + 2Cl_2$$

Long time-series

Sporadic

Long time-series

Since 2004

$$Cl_y = HCl + ClONO_2 + ClO + HOCl + 2Cl_2O_2 + 2Cl_2$$

Estimating $Cl_y$ is hampered by lack of observations

# Observations of HCl

- HCl
  - 1991-2005: UARS HALOE
  - 2004-present: SCISAT ACE
  - 2004-present: Aura MLS
  - 1991, 1993, 1994: Shuttle ATMOS

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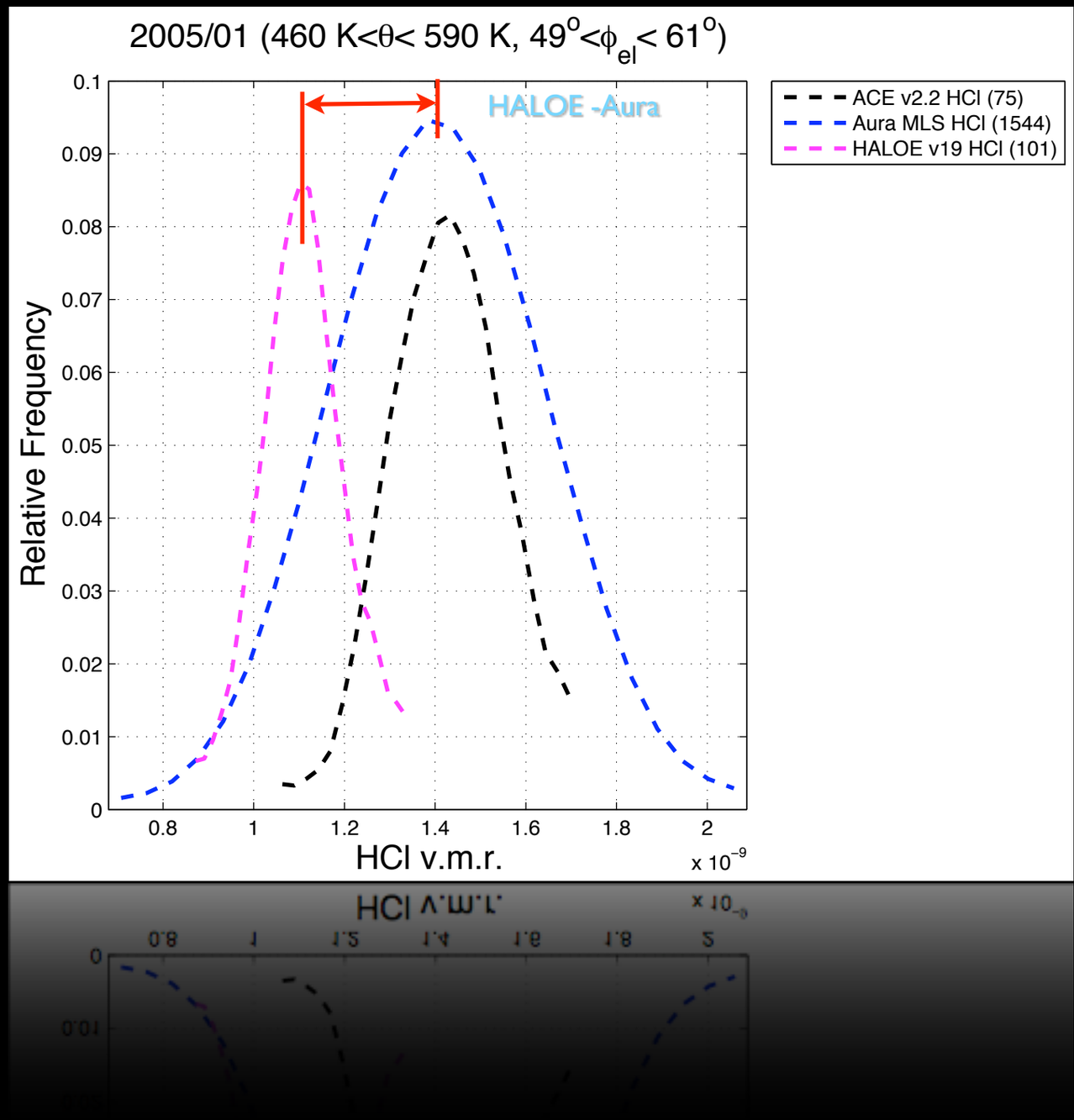
Estimating $Cl_y$ is hampered by inter-instrument biases

# HCl

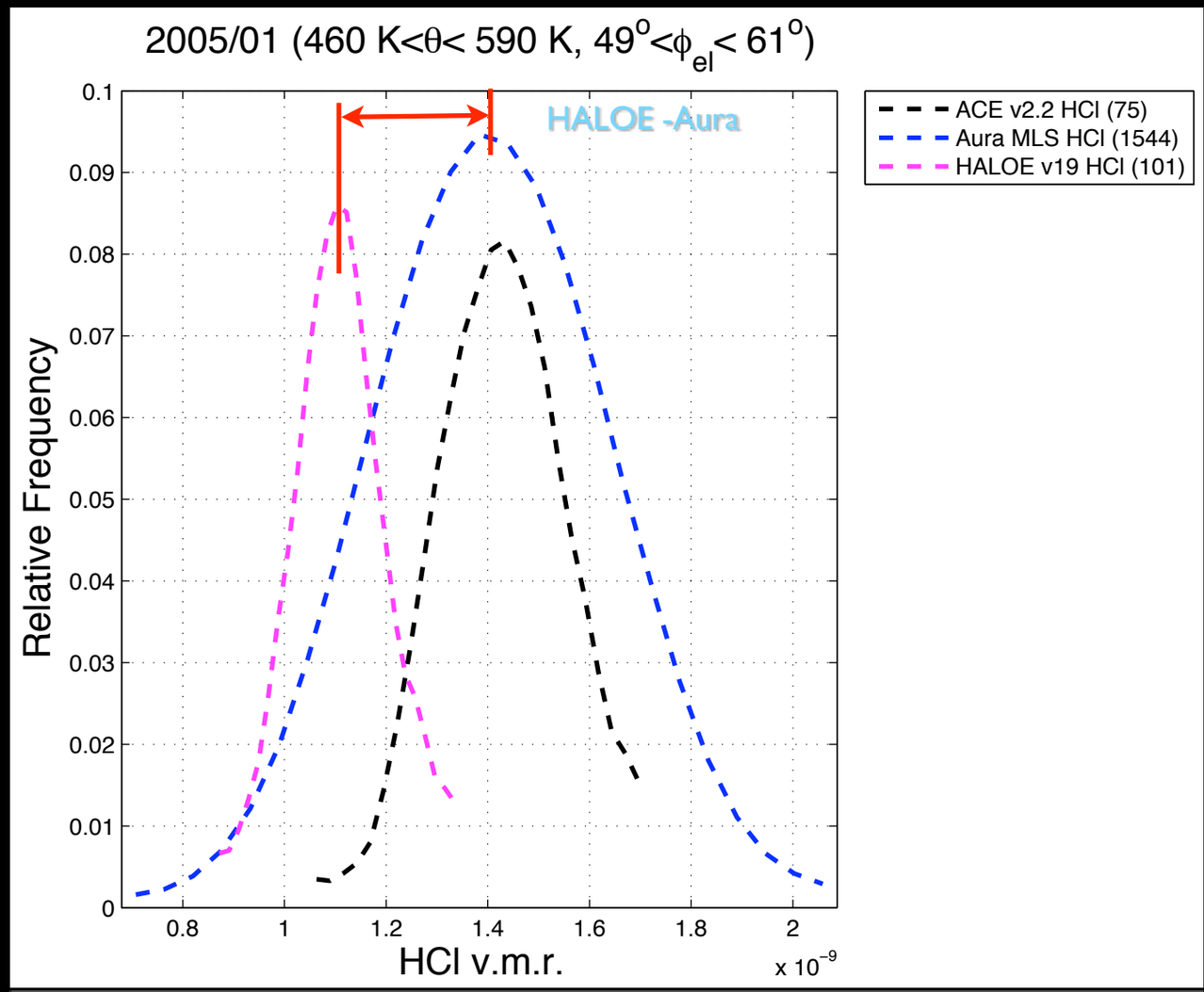
http://www.pdfcentral.info/




# Using PDFs for Bias Detection

# HCl

http://www.pdfcentral.info/




| Instrument | Temporal Coverage | Reference | Median Observation Uncertainty |
|---|---|---|---|
| ACE | 2004-2006 | *Bernath et al.* [2005] | 8% |
| ATMOS | 1991, 1993, 1994 | *Zander et al.* [1992] | 8% |
| Aura MLS | 2004-2006 | *Froidevaux et al.* [2006] | 12% |
| HALOE | 1991-2005 | *Russell et al.* [1993] | 4% |

# Using PDFs for Bias Detection

# HCl

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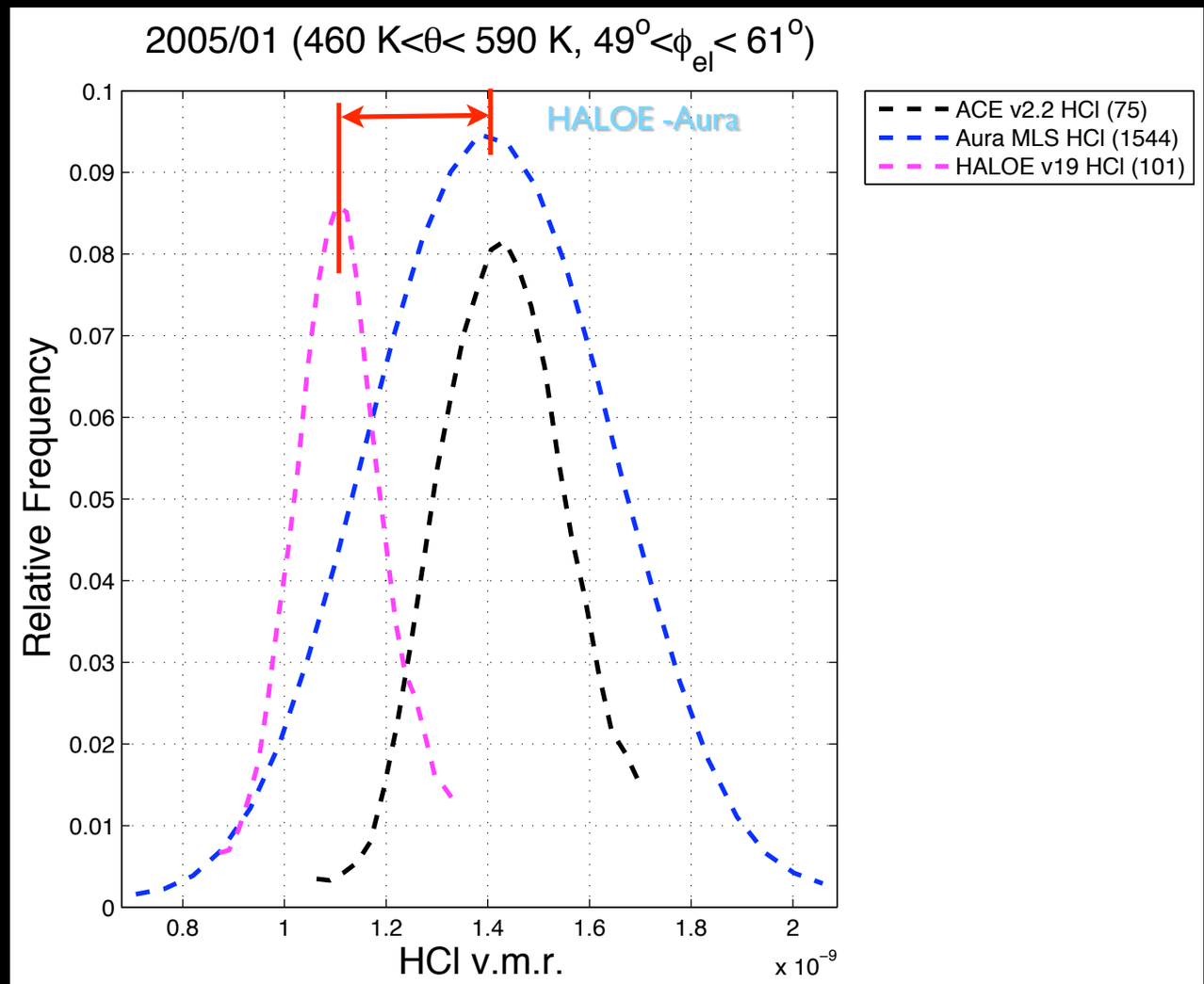


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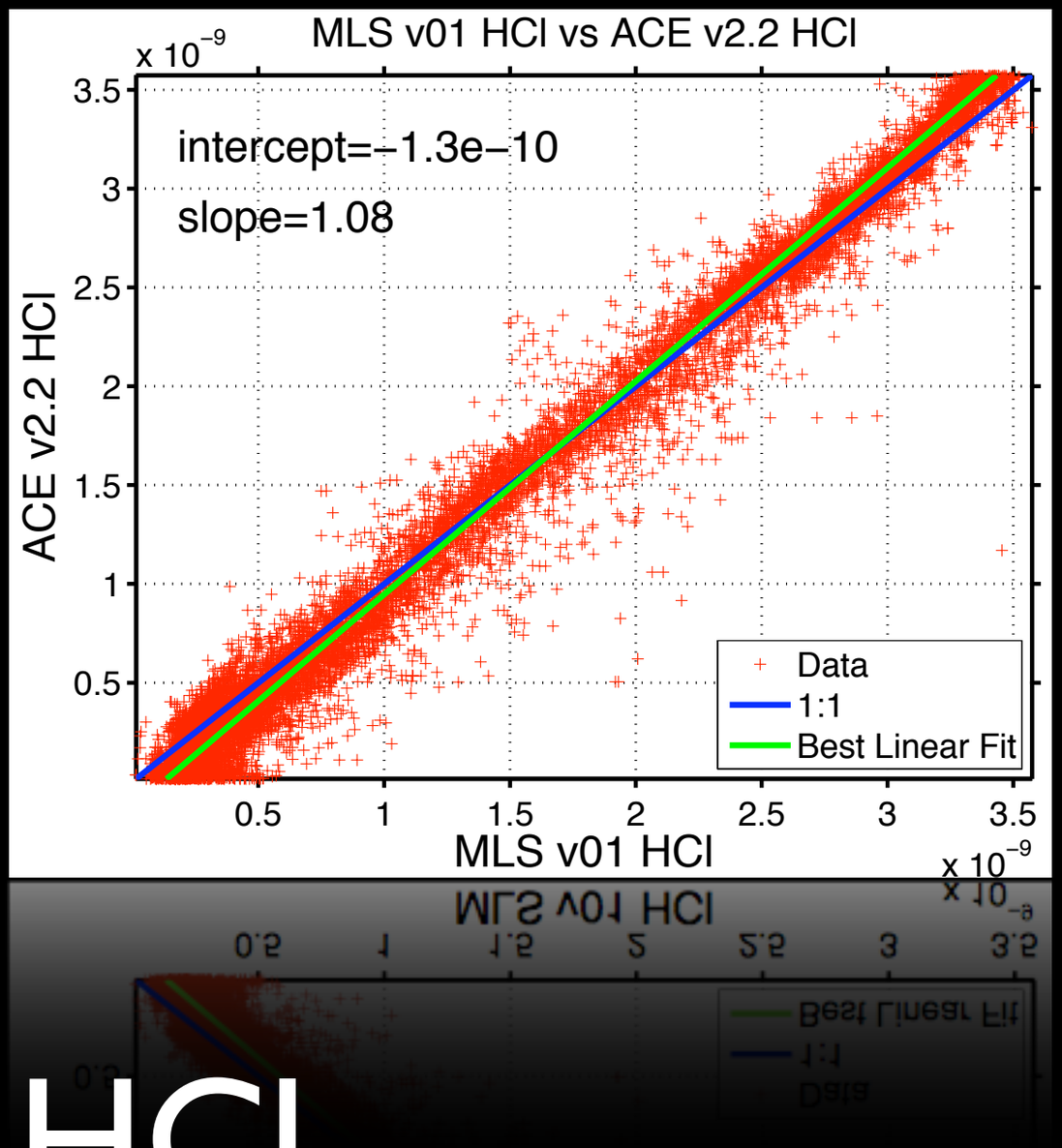
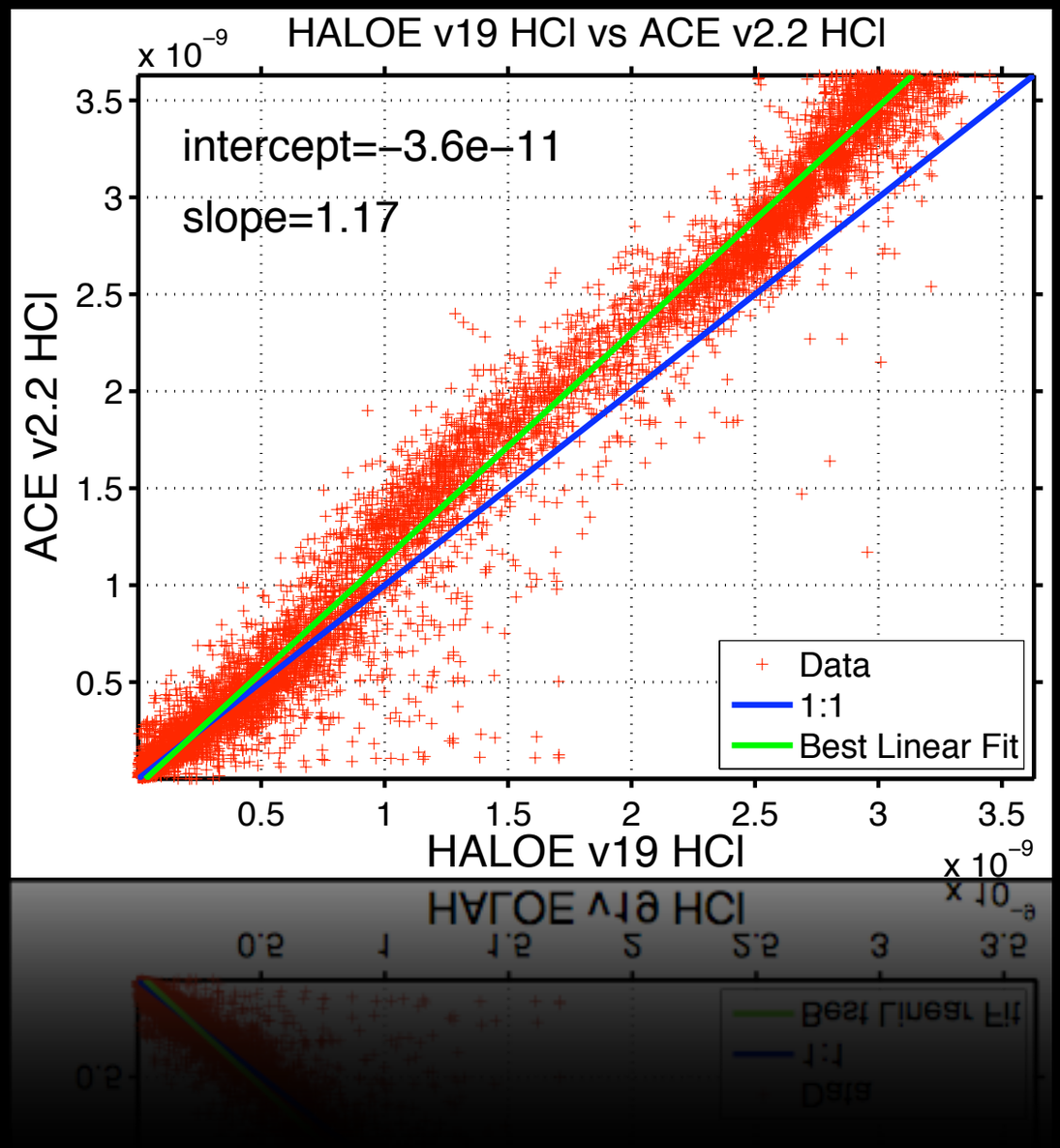
If we now repeat this globally for all periods of overlap

# Using PDFs for Bias Detection

Global Comparison from
October 2004 - present



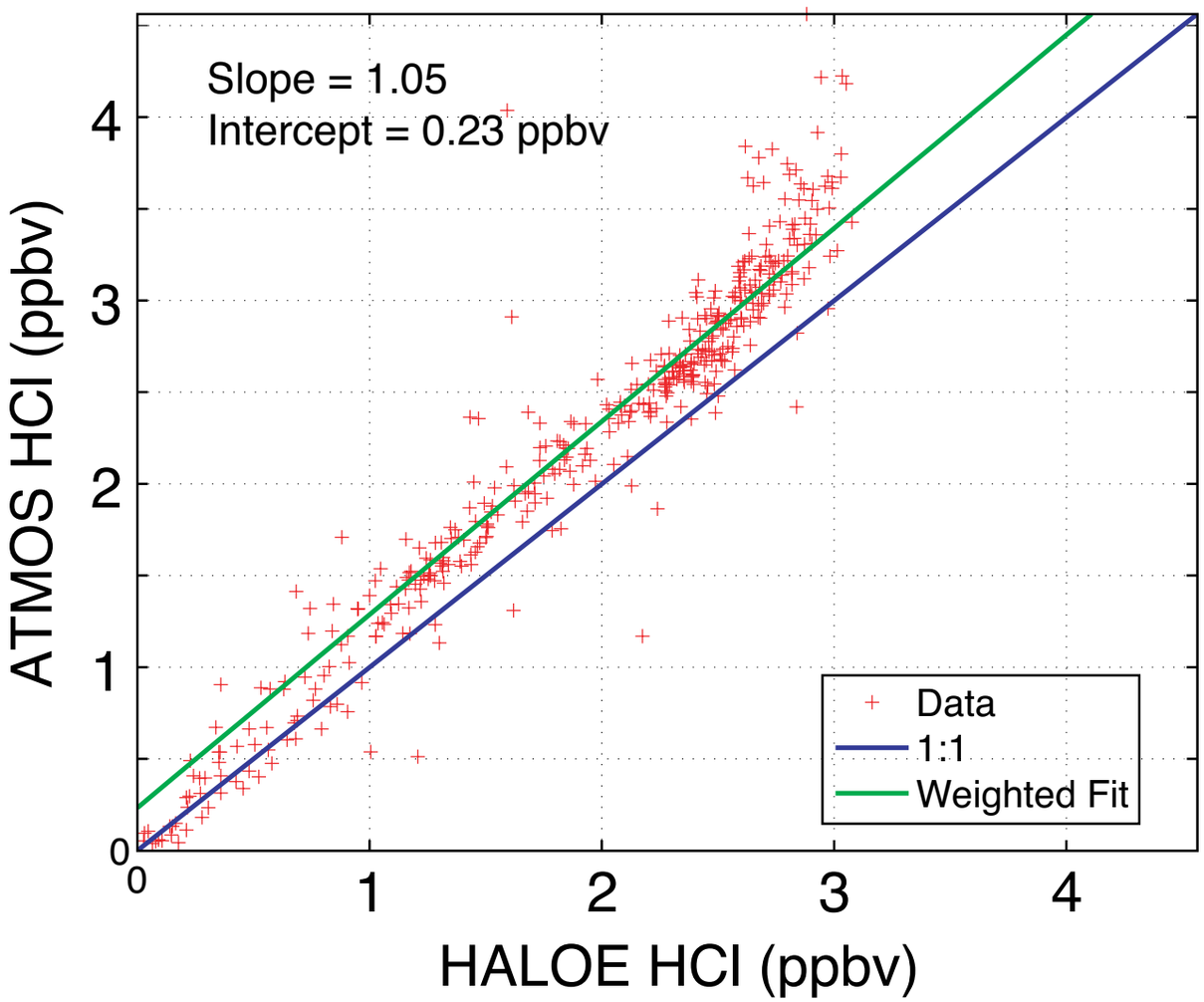

Global Comparison from
January 2004 - November 2005



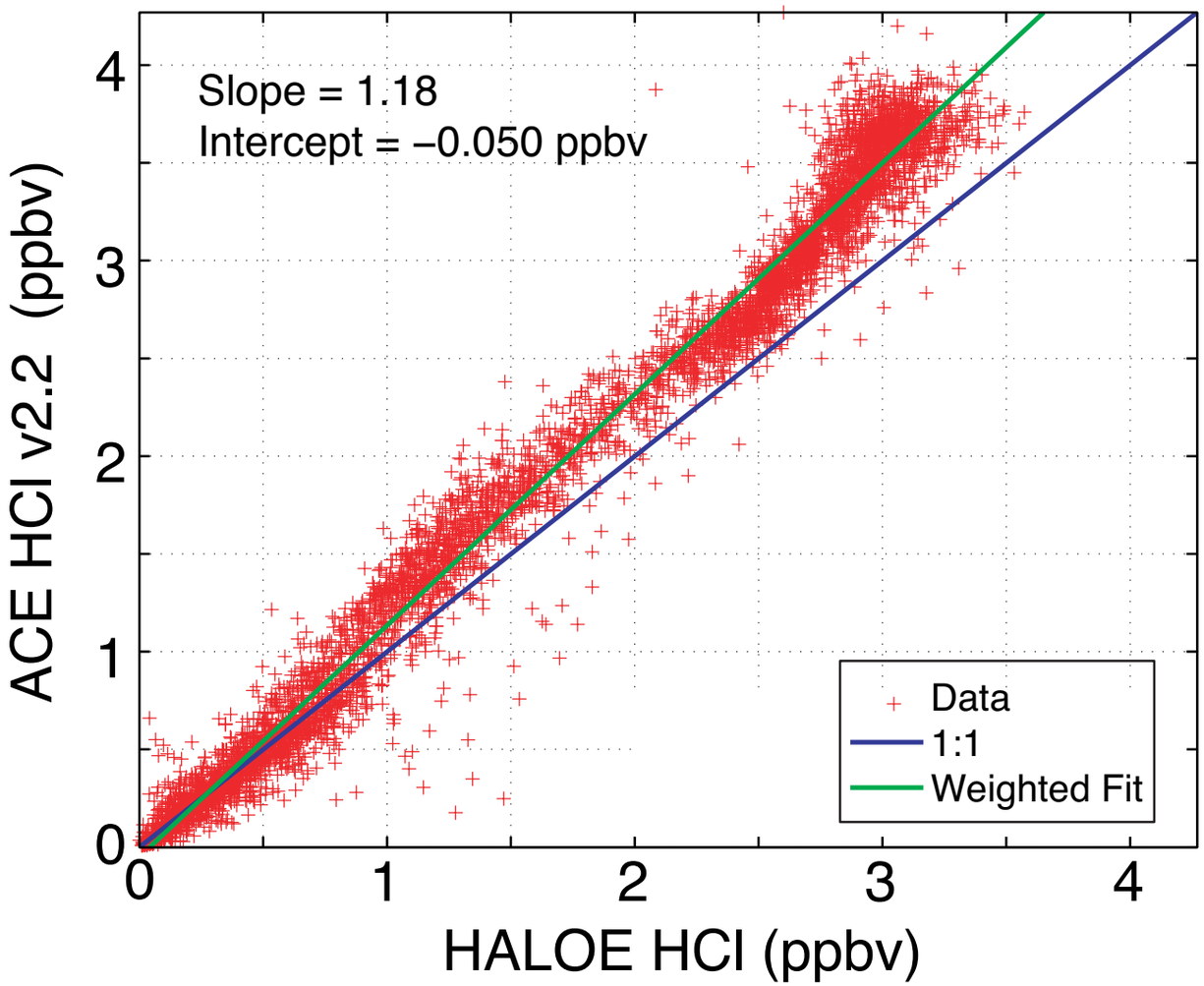

# HCl

# A Global View

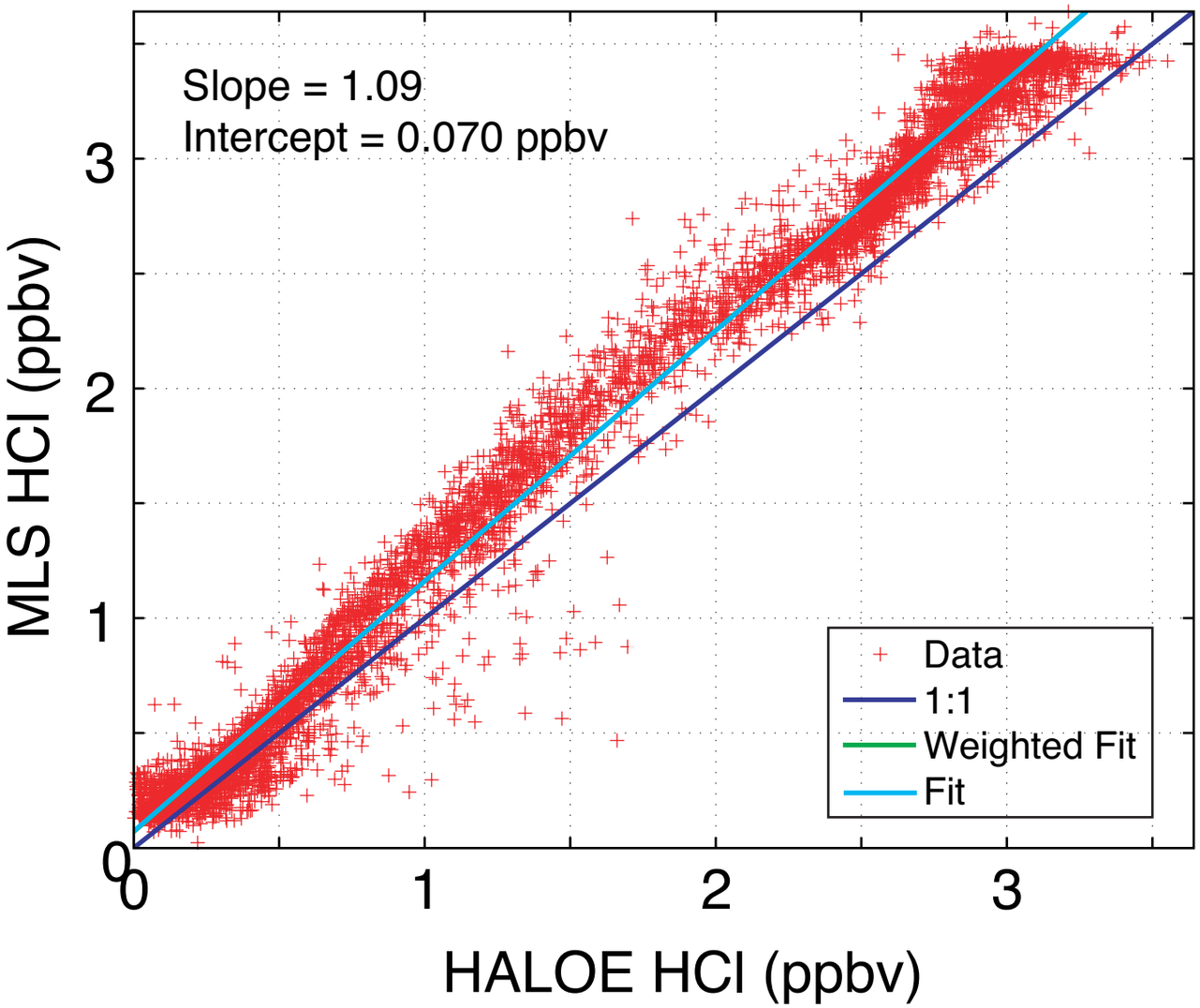
# HCl Inter-comparisons



# HCl Inter-comparisons



# HCl Inter-comparisons



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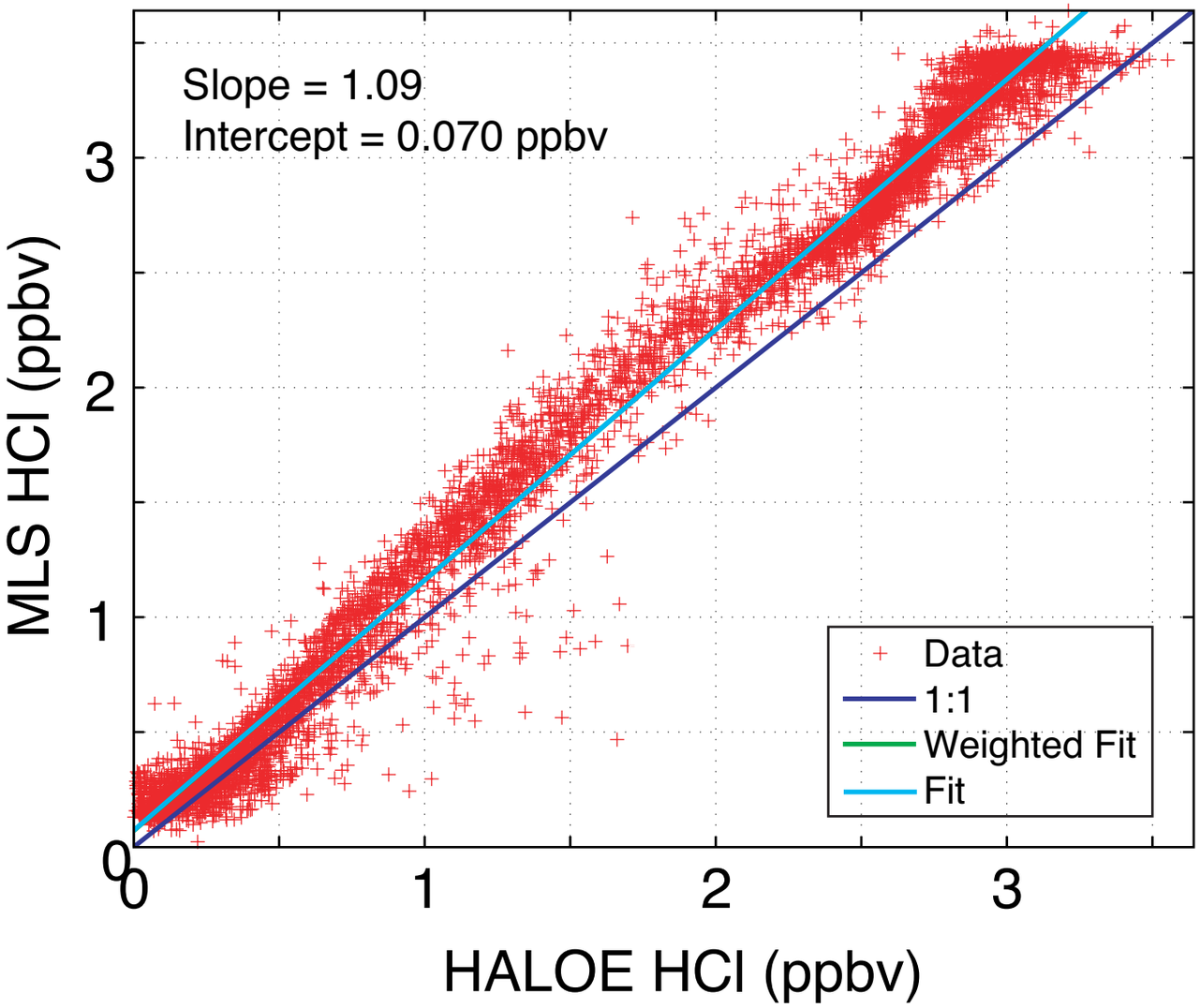
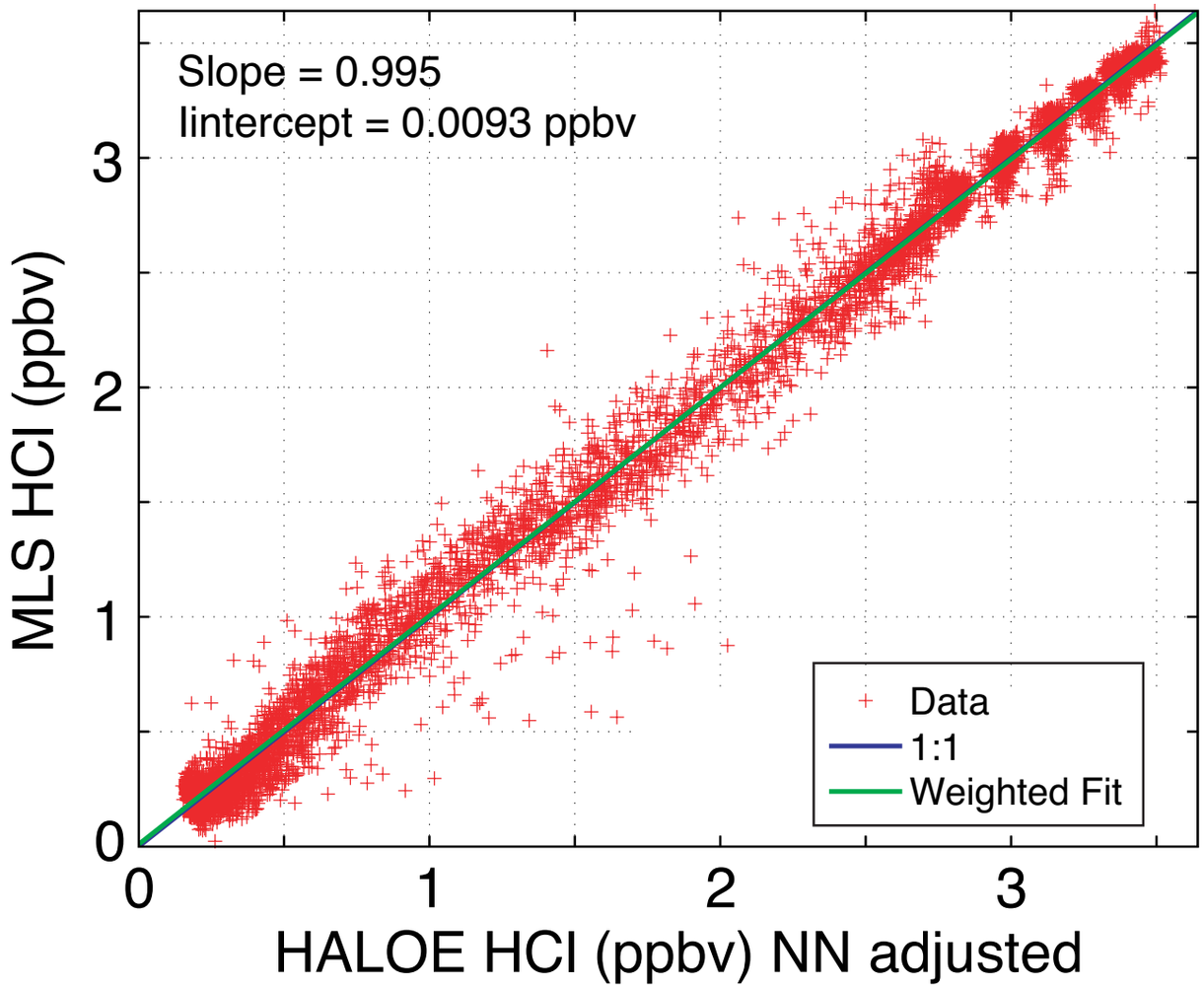
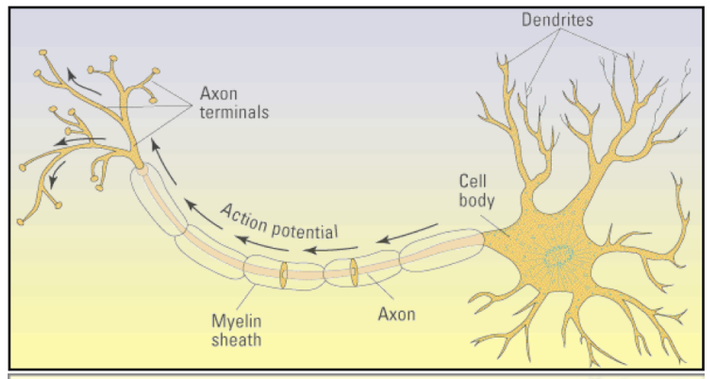
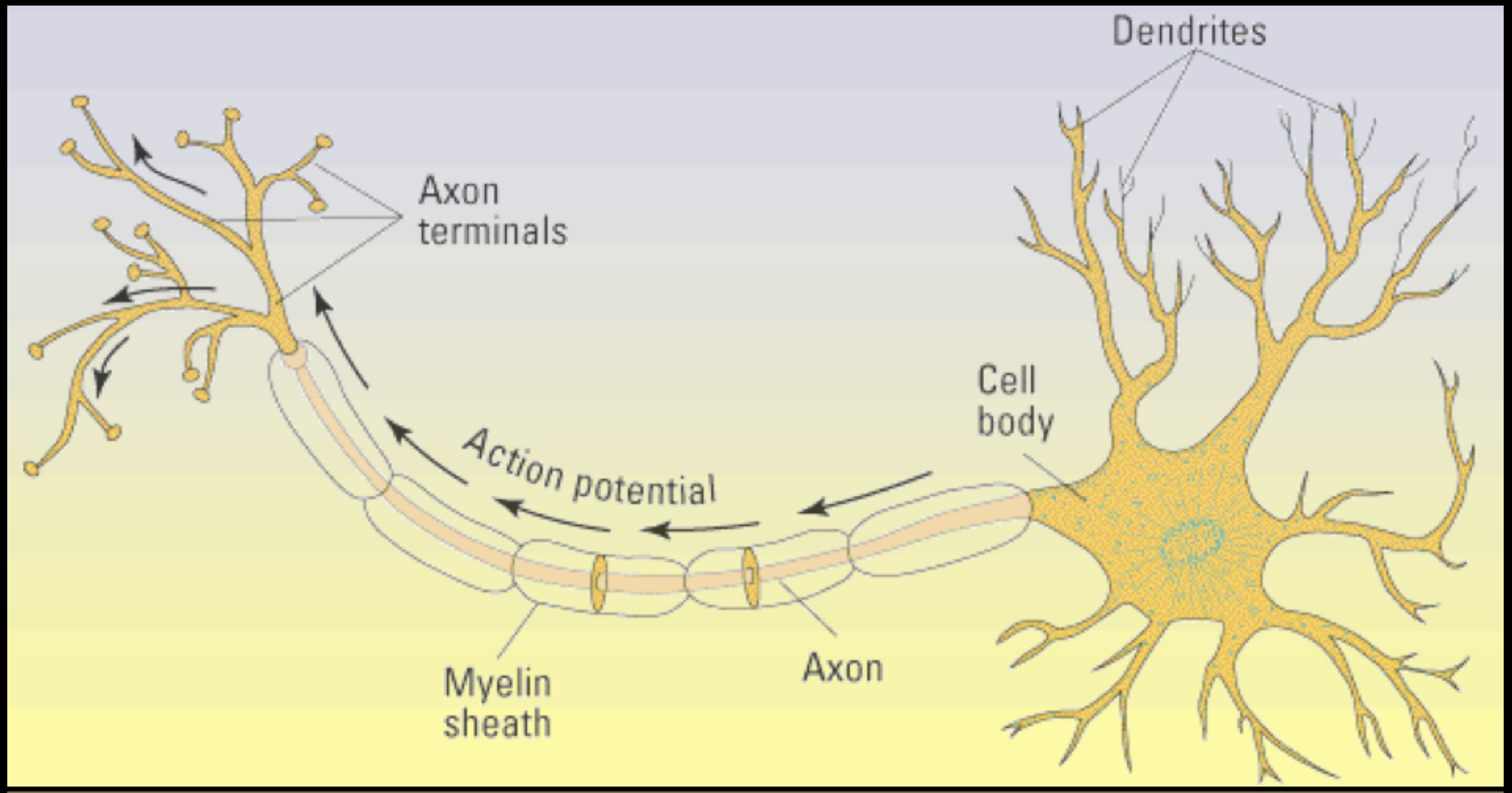


# Neurological algorithms



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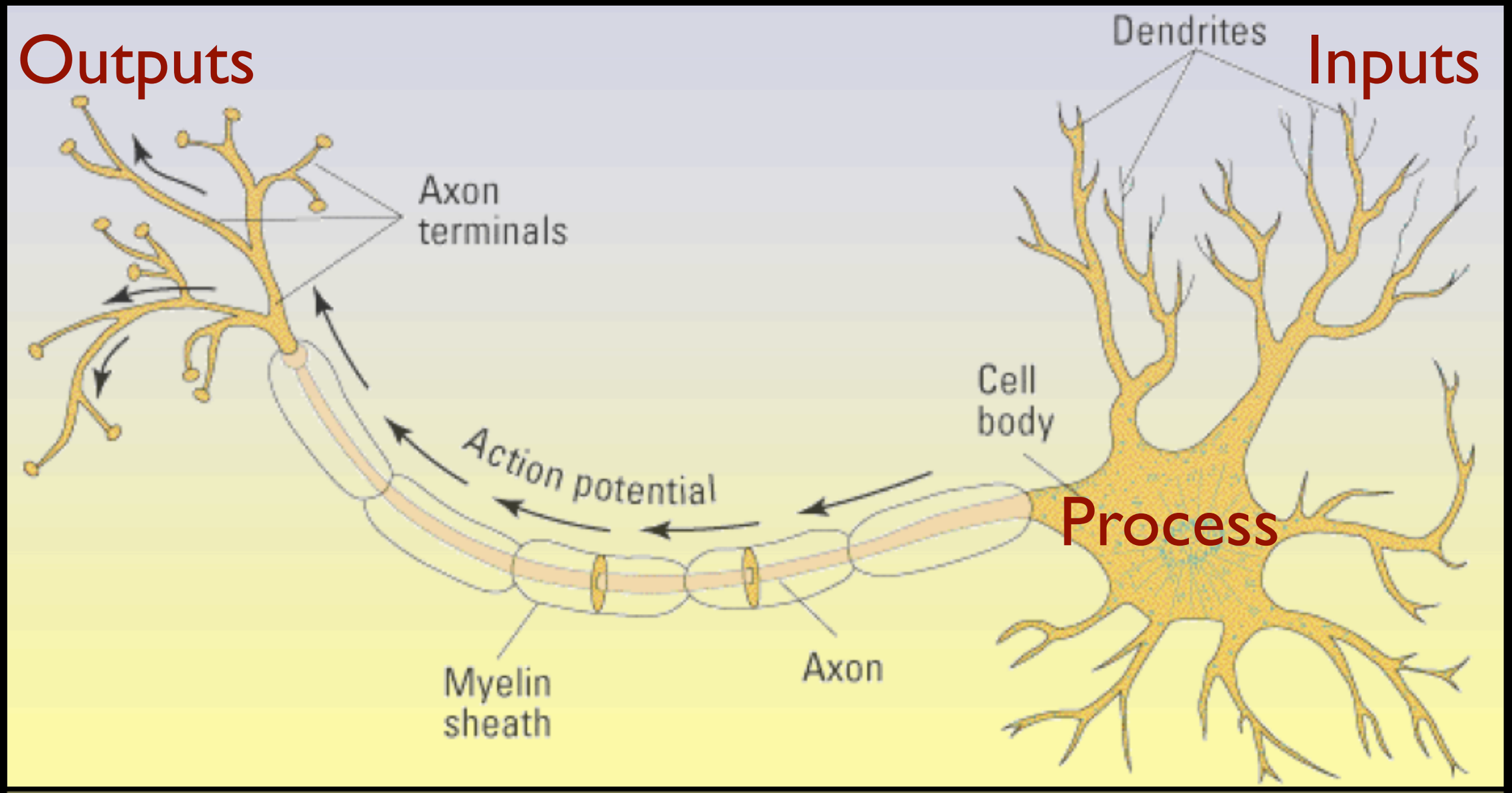
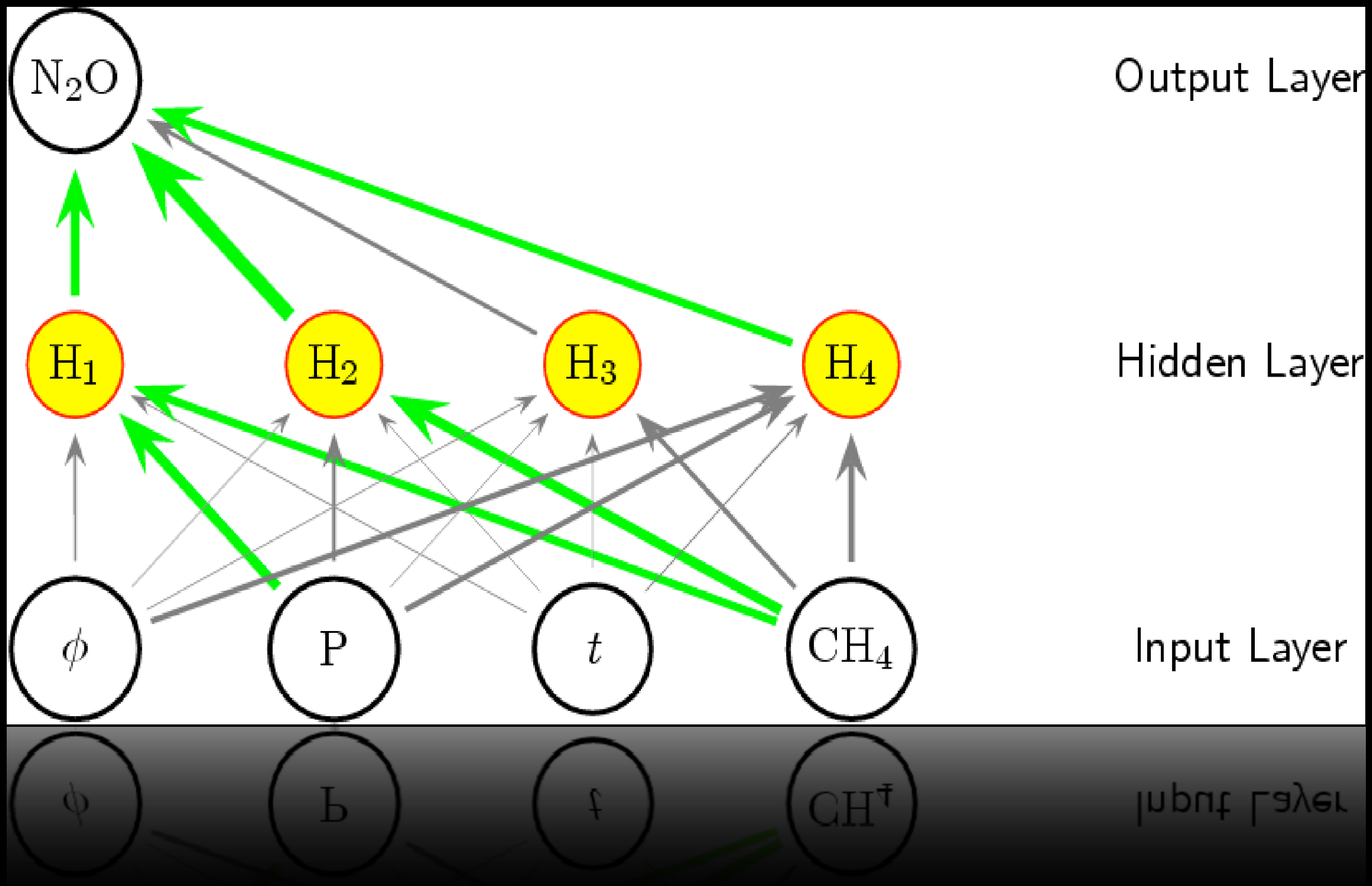


# An example neural network



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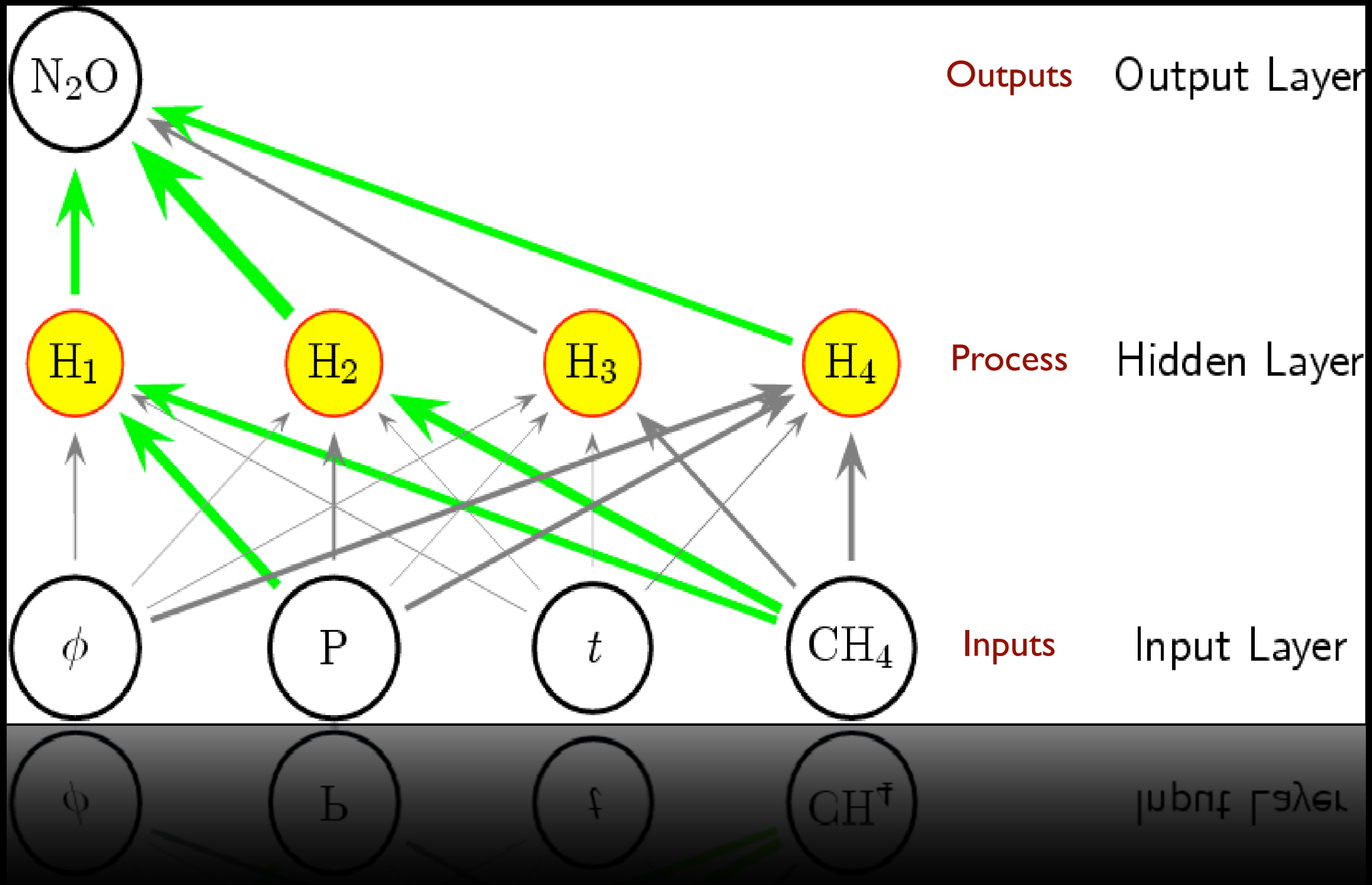
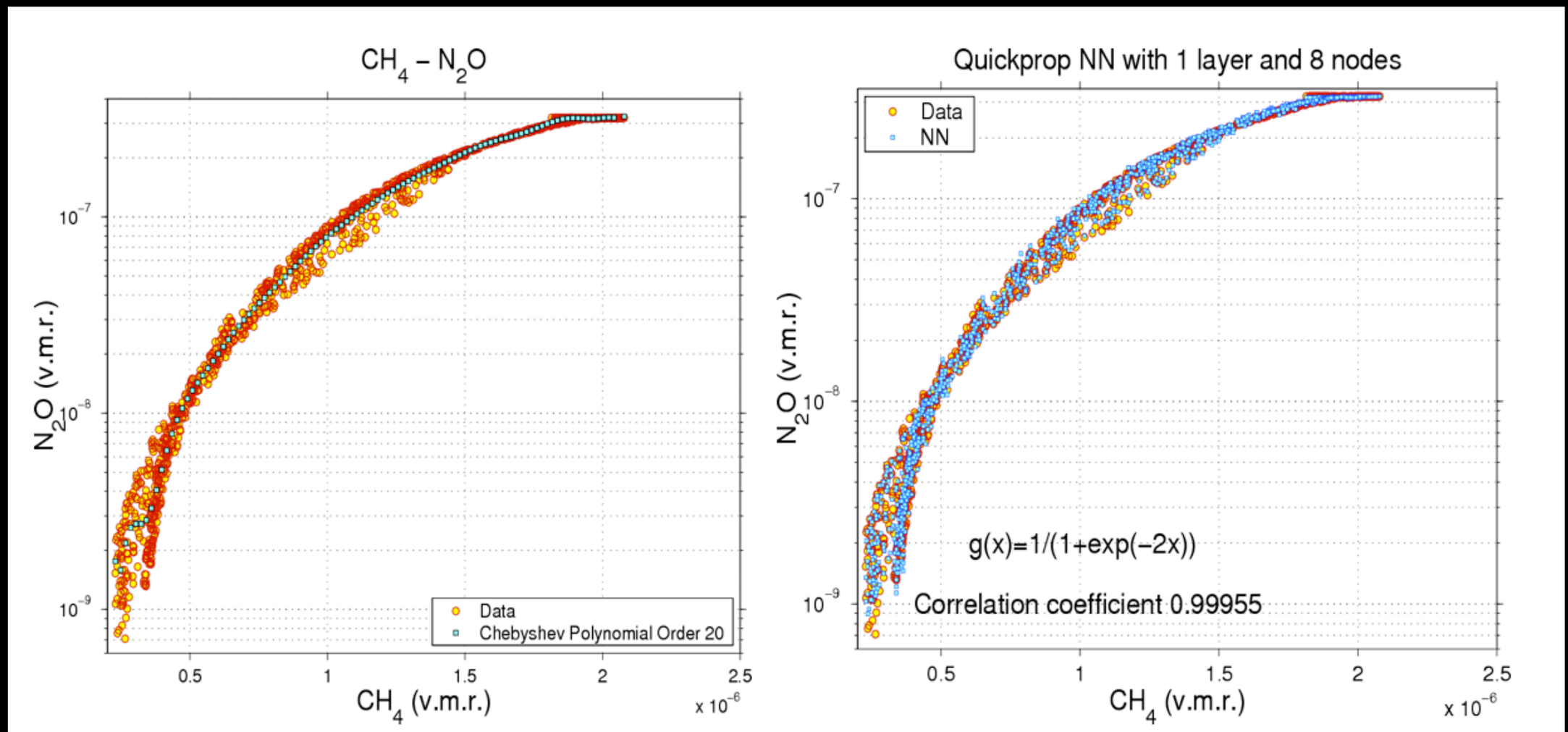
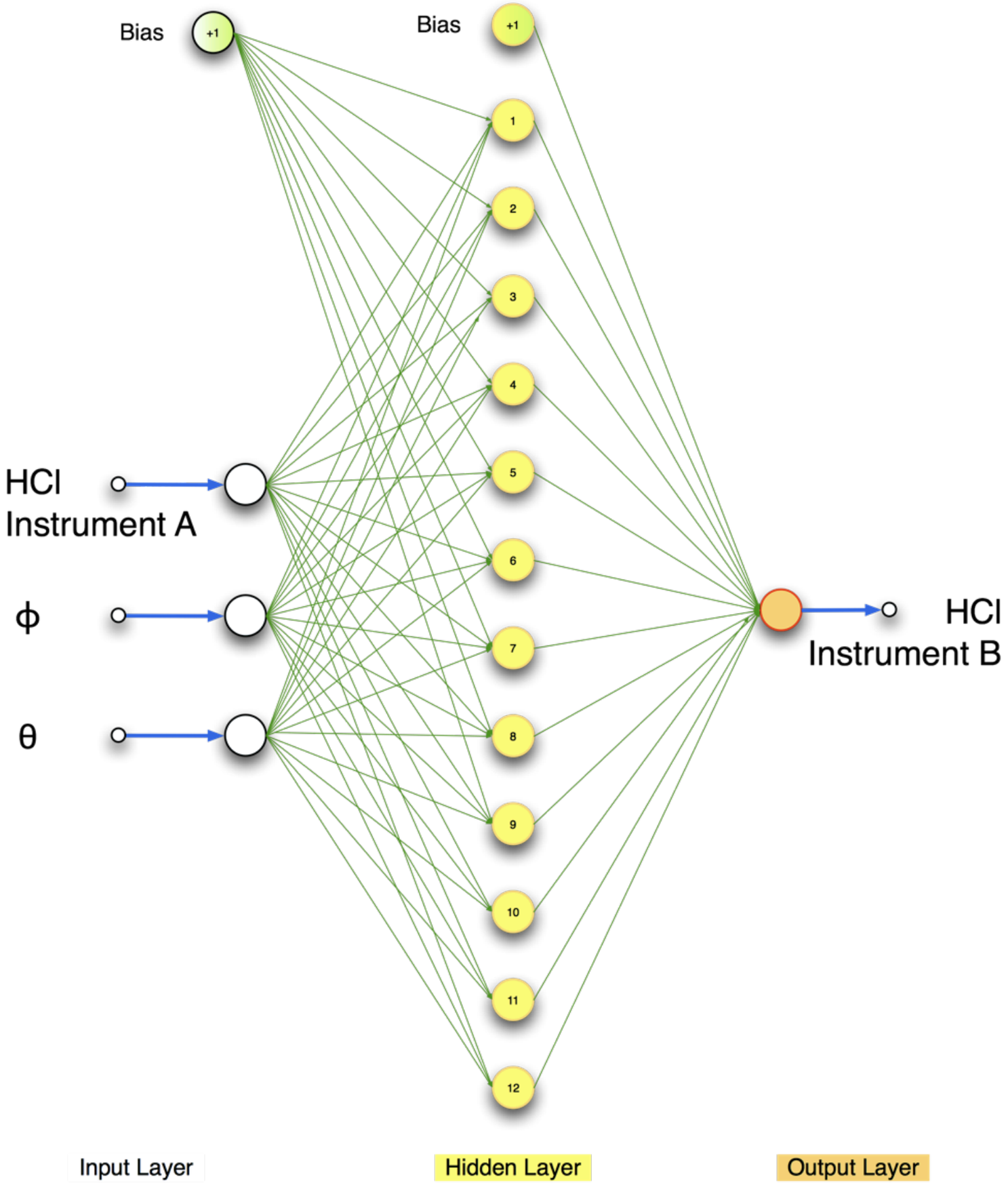


# An example neural network




Bias
+1
Bias
+1
1
2
3
4
5
6
7
8
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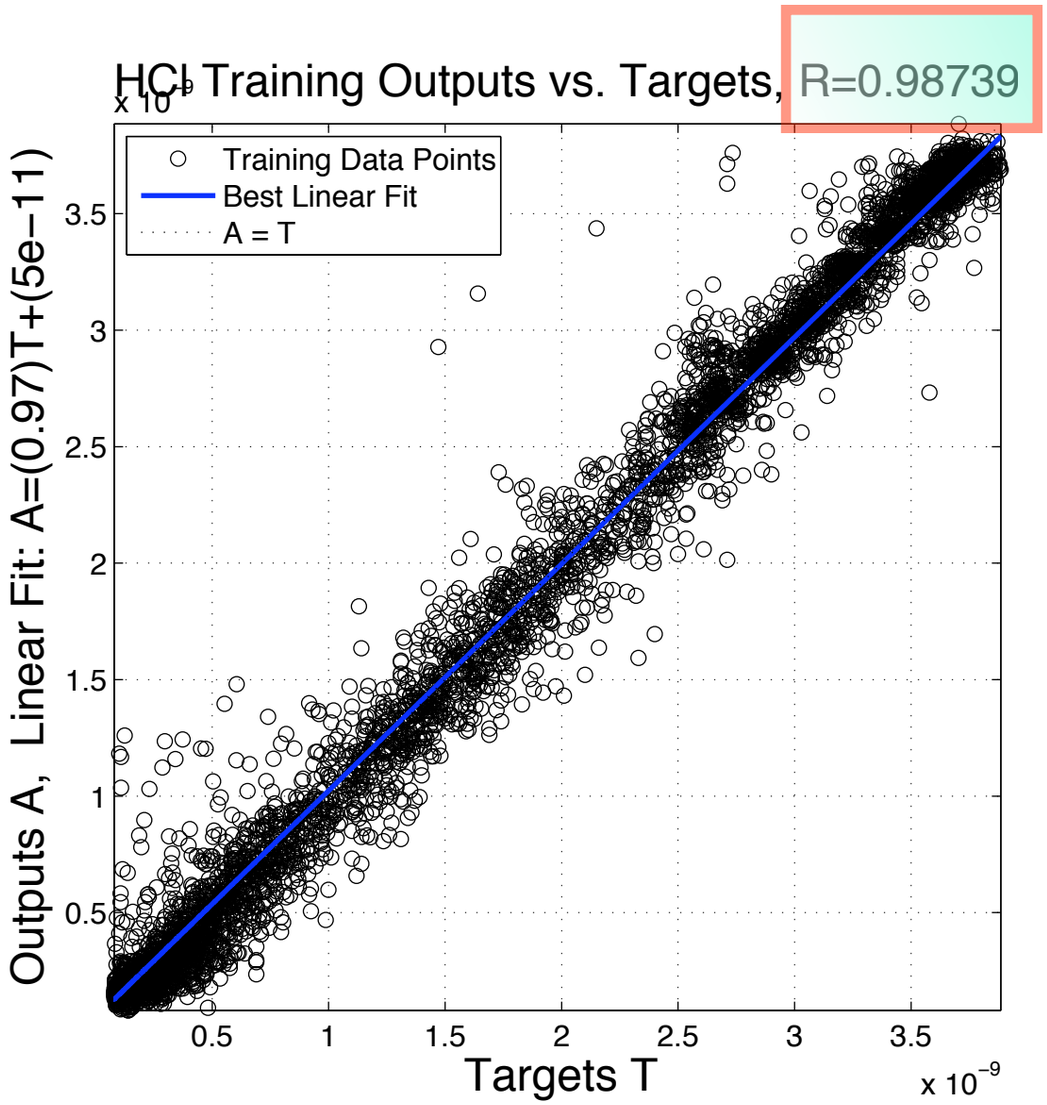
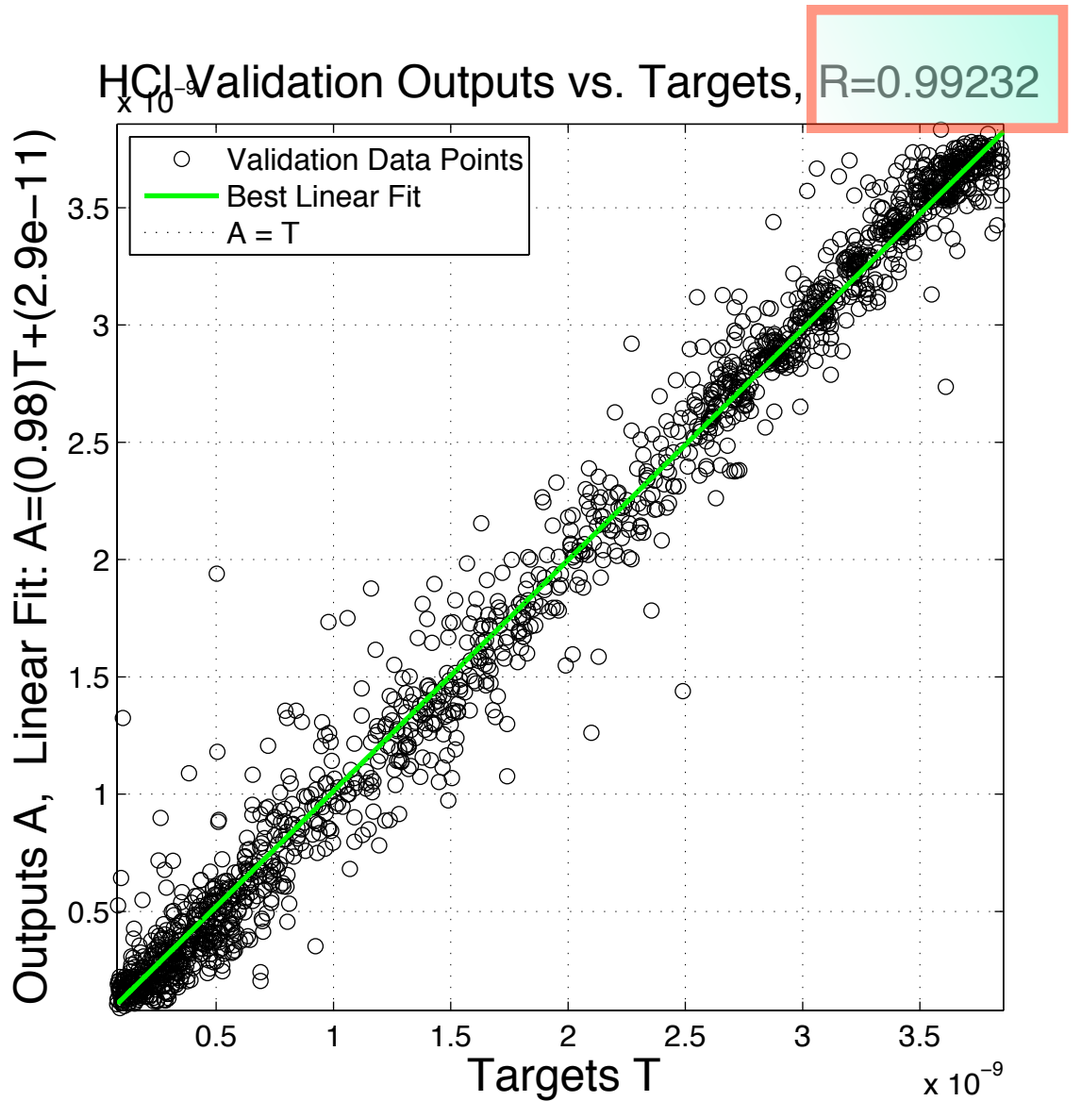
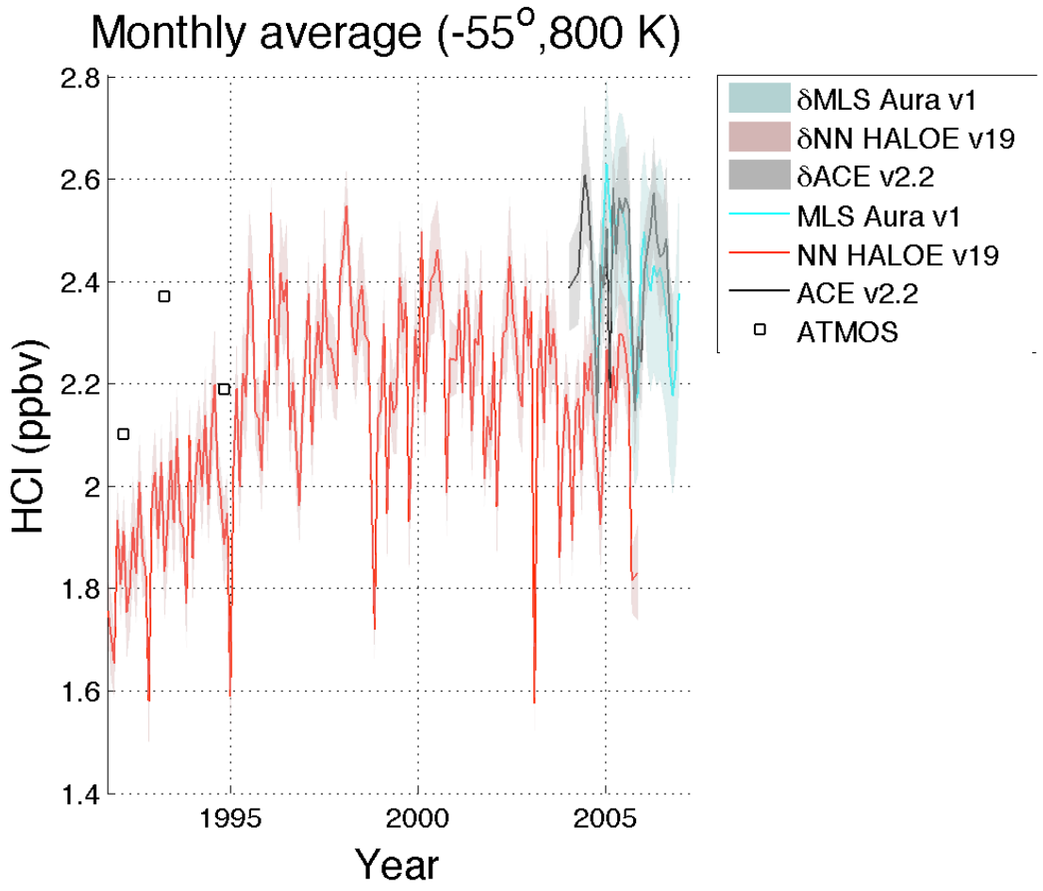
10
11
12
HCl
Instrument A
ϕ
θ
HCl
Instrument B
Input Layer
Hidden Layer
Output Layer

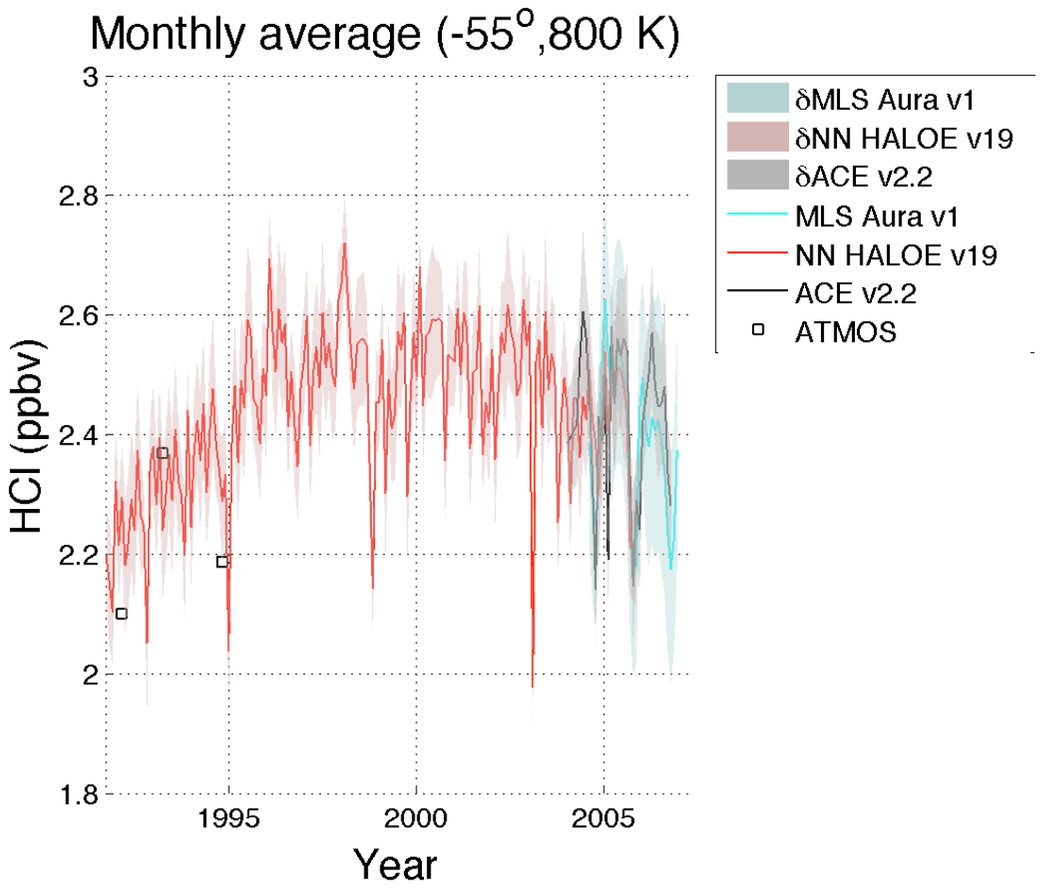


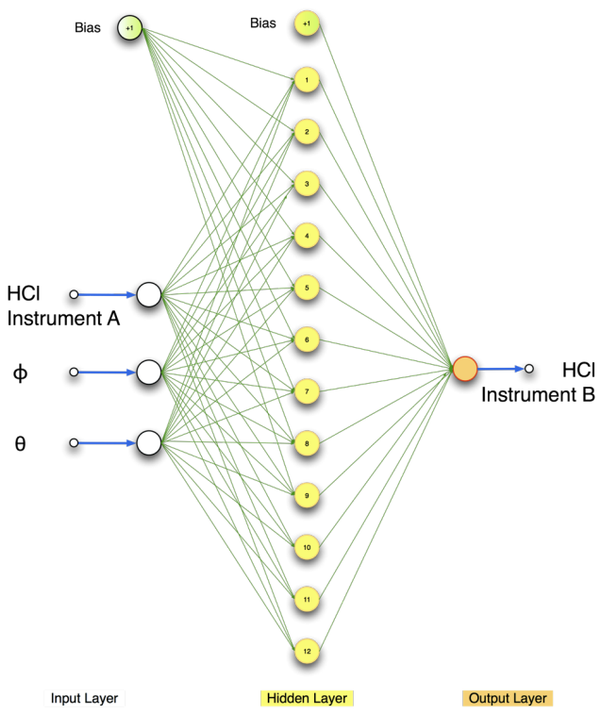




Totally independent validation

# Re-calibration using a Neural Network



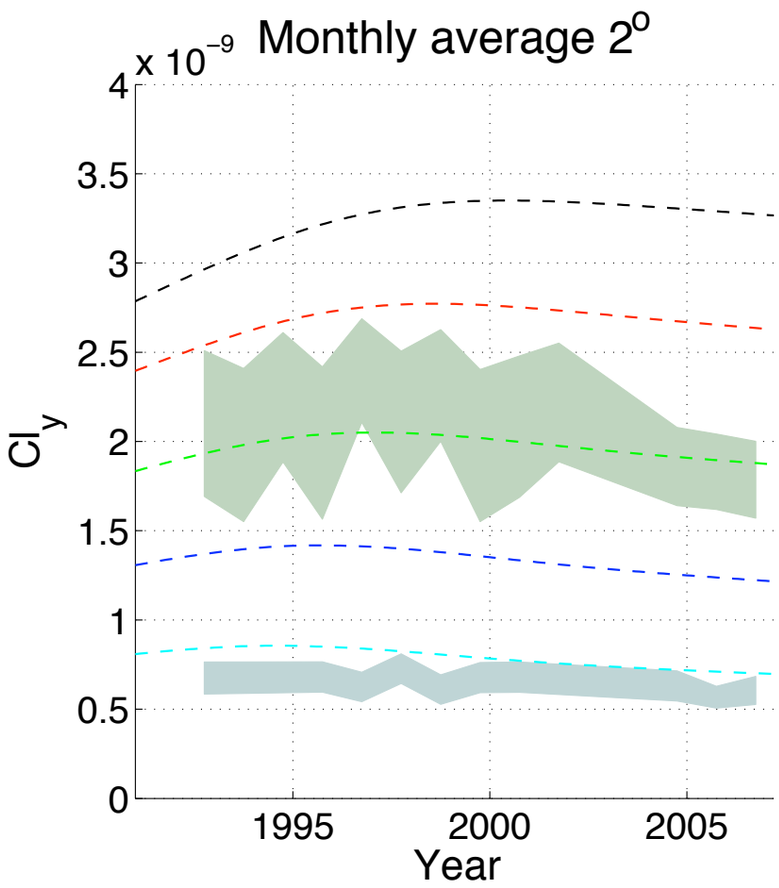



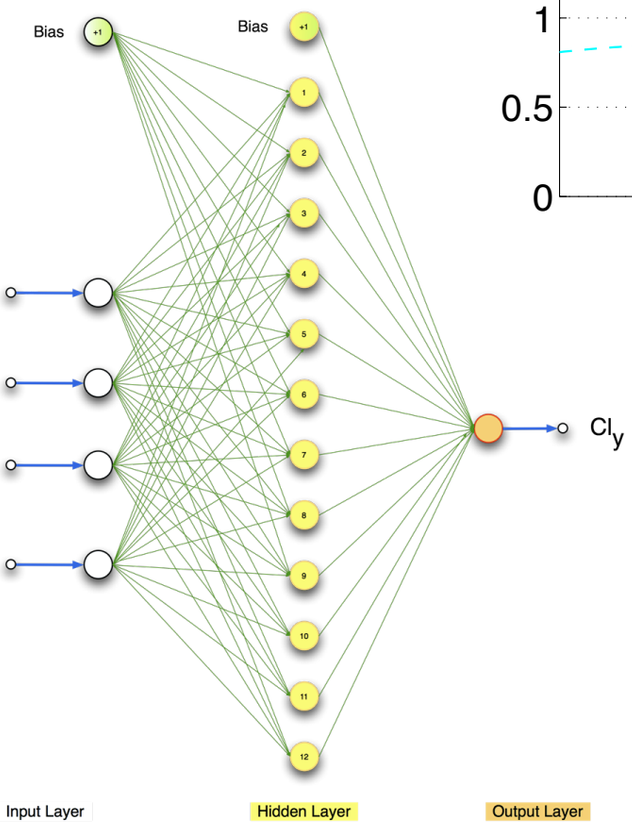



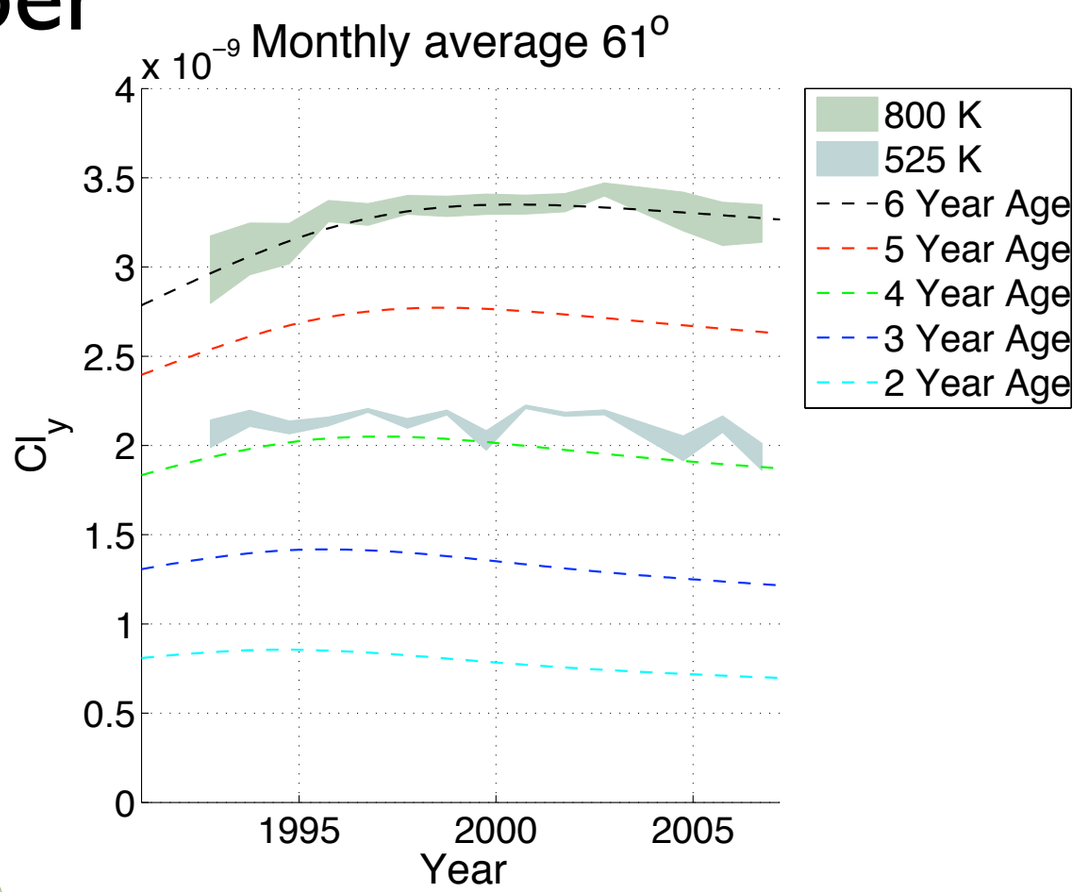

# Applied Neural Network Re-calibration to HALOE

# Long-term continuity

# October



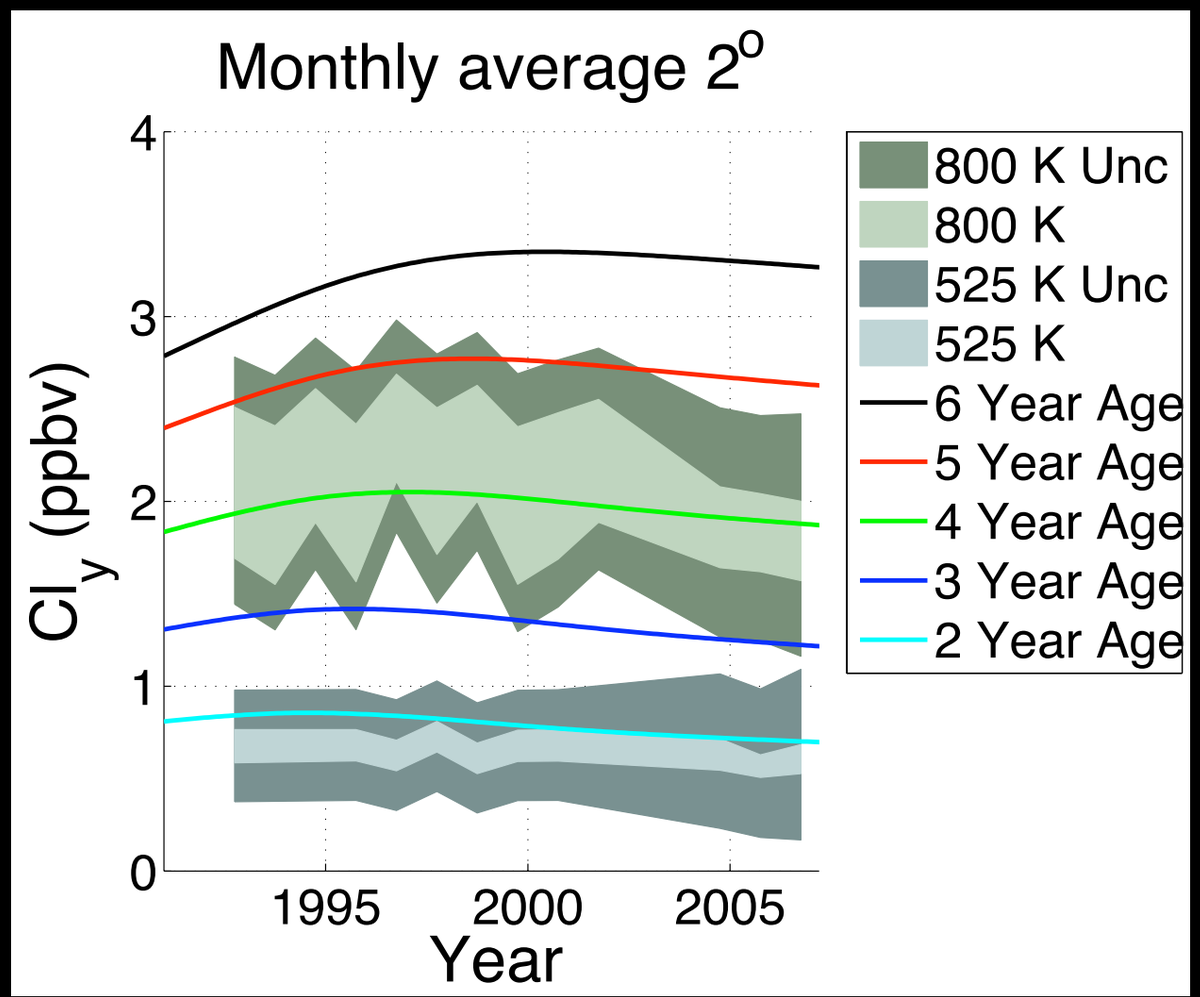



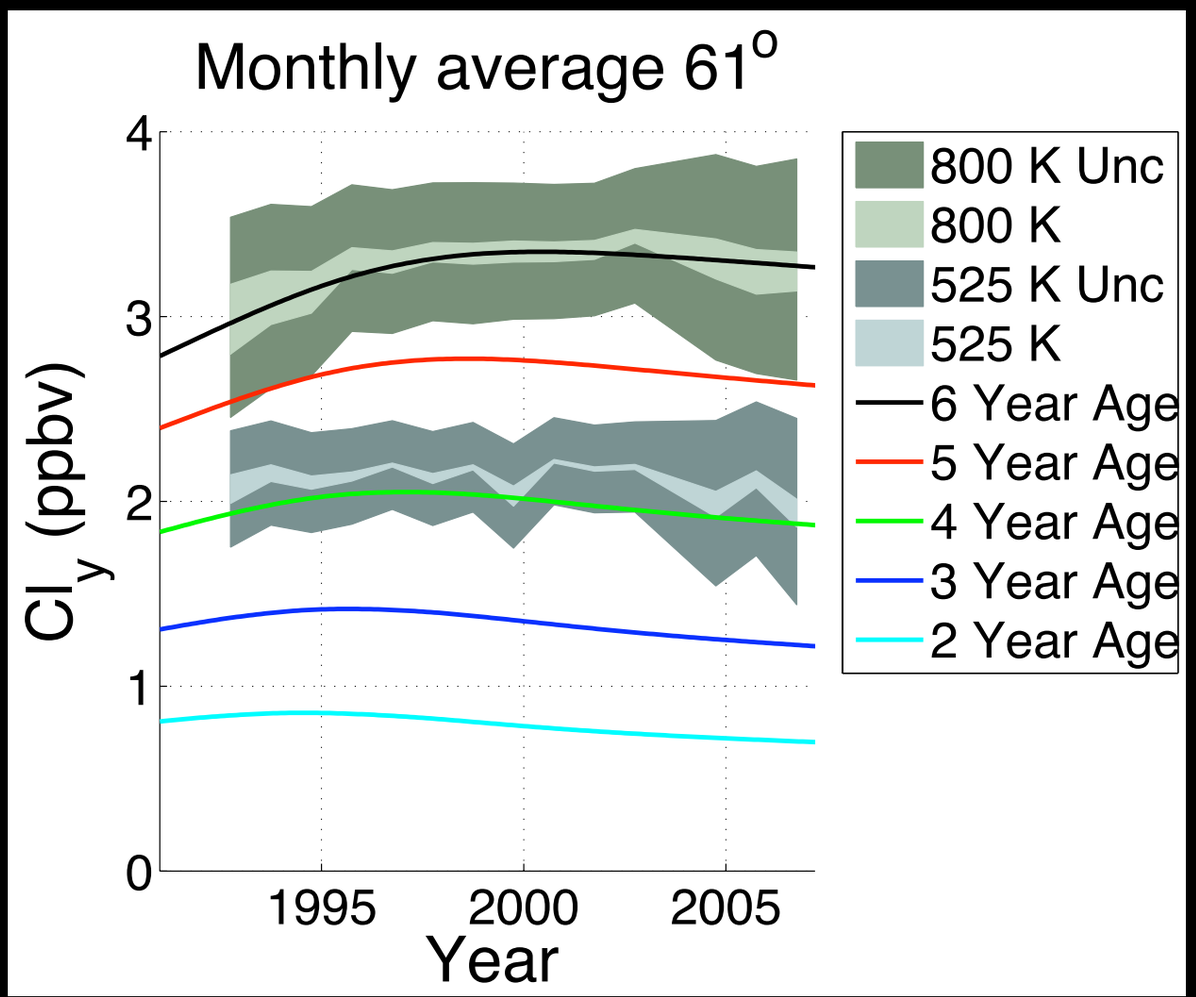




Use neural networks to infer Cly from HCl, $CH_4$, $\phi_{pv}$, and $\theta$.

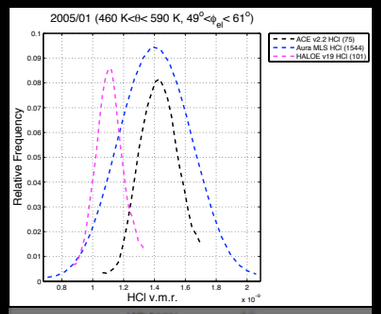
# Long-term continuity for $Cl_y$

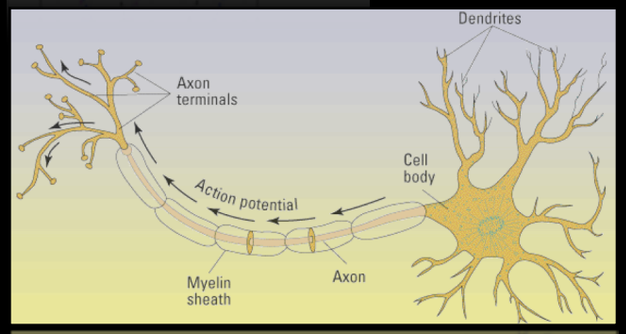
# October

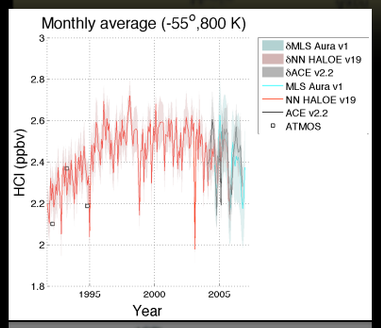


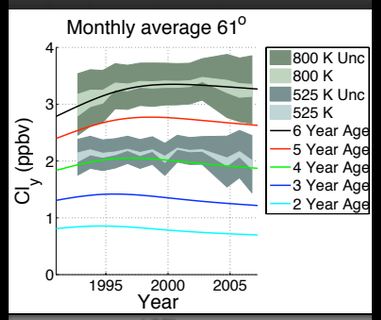



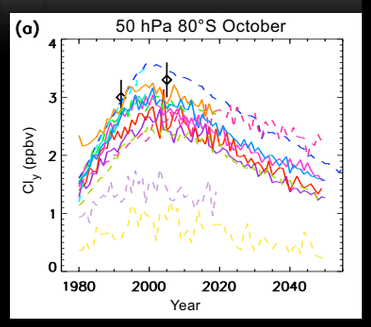

# Long-term continuity for $Cl_y$





# Summary

- Used PDFs to diagnose inter-instrument biases
  - www.PDFCentral.info
- Use neural networks to correct for inter-instrument biases
- Produce consistent time-series with full uncertainty estimates
- Use neural networks to infer Cly from HCl, $CH_4$, $\phi_{pv}$, and $\theta$.
- A knowledge of the Cly time variation is useful for attributing changes in stratospheric ozone to changes in halogens, and for assessing the realism of chemistry-climate models.
- Other uses: Long-term Kalman filter data assimilation (http://www.cdacentral.info/).